



Use of SELEXOL Solvent for Hydrocarbon Dewpoint Control and Dehydration of Natural Gas



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Abstract

SELEXOL solvent is a physical solvent which is a polyalkylene glycol ether derivative. It has been widely used especially in natural gas applications requiring selective absorption of sulfur compounds and bulk removal of CO₂. Its traditional applications also include the treatment of refinery off-gas, landfill gas, ammonia synthesis gas, and flue gas. Use of SELEXOL solvent for two non-traditional uses - hydrocarbon dewpoint control and dehydration - will be discussed in this paper.

A European distribution company has selected SELEXOL solvent to remove CO₂ and to control hydrocarbon dewpoint for five of its peak-shaving plants. Tejas Power has built a plant using SELEXOL solvent to simultaneously control the hydrocarbon dewpoint and dehydrate pipeline gas.

Introduction

SELEXOL solvent has been around since the late 60's. It was first patented by Allied Corporation, then sold to Norton in 1982 and acquired by Union Carbide in 1990. It is mainly used to remove CO₂, H₂S, and other components from natural gas or synthetic gas streams. SELEXOL solvent removes gases by physical absorption or solubility rather than by chemical reaction as in, for example, amine systems.

Historically, in applications in which the feed stream contained more than about four percent hydrocarbons (C₂+), any physical solvent has been considered unsuitable because too much of the hydrocarbons would be co-absorbed with the attendant problems in recovery of the hydrocarbons and regeneration of the solvent. However, SELEXOL solvent technology has benefited from the years of experience its marketers have gained in resolving hydrocarbon coabsorption problems. As a result, an area that was once considered a negative for SELEXOL solvent, absorption of hydrocarbons, has now been developed into a marketable characteristic of the solvent.

Hydrocarbon Co-Absorption

All hydrocarbons are soluble in physical solvents to some extent. The actual solubility of a component in SELEXOL solvent is defined by its equilibrium constant ($K' = y/x'$, where y is the mole fraction of the solute in the vapor phase and x' is the mole fraction of the same compound in the liquid phase considering only the presence of the specific component and SELEXOL solvent). However, K' values taken alone give an incomplete picture and can be misleading. Care has to be taken to differentiate between the solubility of hydrocarbons in SELEXOL solvent, as defined by K' values, which are indicative of the ability of SELEXOL solvent to absorb hydrocarbons from the gas phase, and the liquid phase solubility which is defined by x' values. The relative solubility of the gases in SELEXOL solvent, shown in Table 1, suggests that as the molecular weight of a hydrocarbon increases, the K' value decreases, suggesting increasing solubility. In fact, hydrocarbon solubility in SELEXOL solvent does increase with molecular weight, but only up to a particular limit, ($x' = x'_{lim}$), for each hydrocarbon. Above this limiting value, the K' values are no longer applicable as the solution is saturated. Further hydrocarbon pick-up from a gas stream would result in the formation of a second phase. This limiting hydrocarbon solubility, as defined by x'_{lim} , has been found to decrease with increasing molecular weight, (see Figure 1 & 2).

Figure 1. The Relationship of K-Value and Molecular Weight in SELEXOL® Solvent

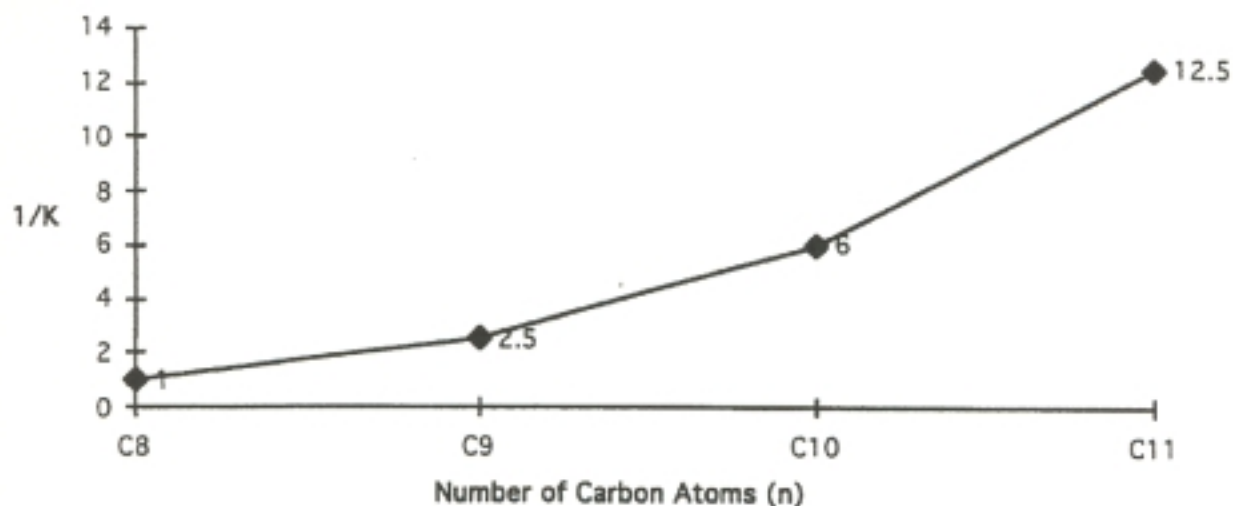


Figure 2. The Effect of Water Concentration and Molecular Weight On Linear Hydrocarbon Solubility in SELEXOL® Solvent

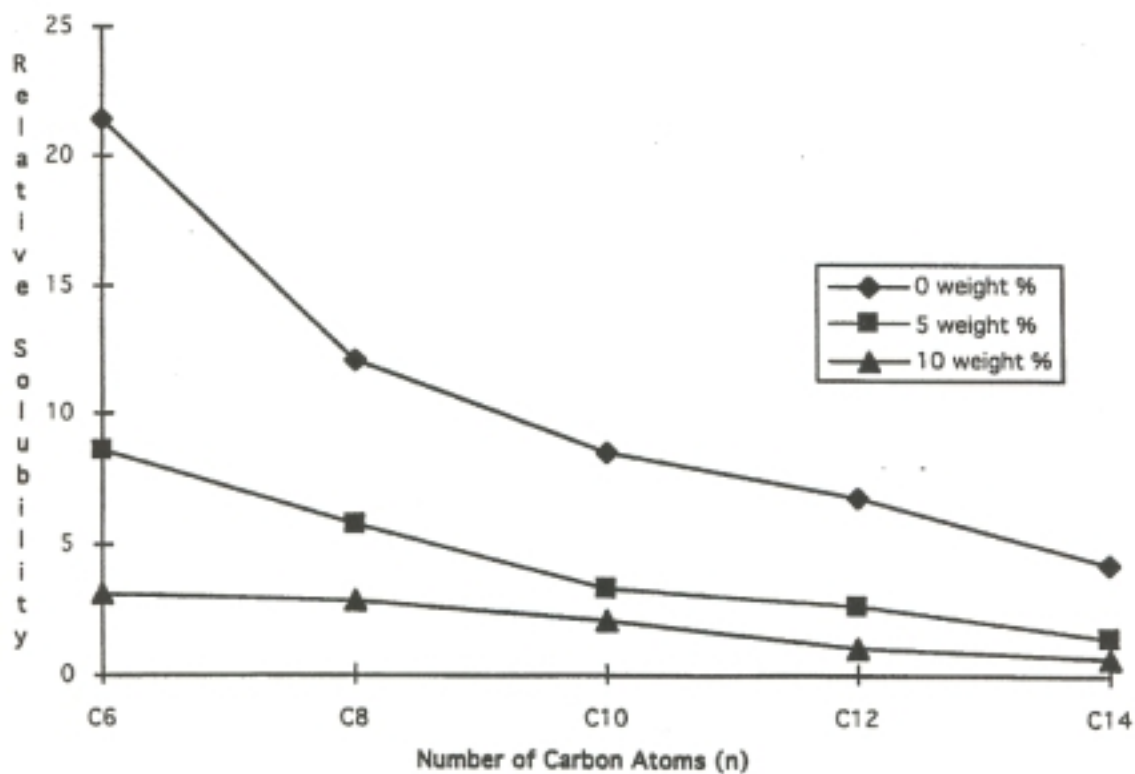


Table 1. Relative Solubility of Various Gases in SELEXOL Solvent

Component	K^1C_2 R= K ¹ Component	Component	K^1C_2 R= K ¹ Component
H ₂	0.03	NH ₃	11
N ₂	0.05	NC ₅	13
CO	0.07	H ₂ S	21
C ₁	0.15	C ₆	26
C ₂	1.0	CH ₃ SH	52
C ₂ H ₄	1.11	C ₇	55
CO ₂	2.3	CS ₂	55
O ₃	2.4	SO ₂	214
IC ₄	4.2	C ₆ H ₆	605
NC ₄	5.5	C ₄ H ₄ S	1270
CO	5.3	H ₂ O	1683
IC ₅	10.5	HCN	2904
C ₂ H ₂	10.5		

Above a certain concentration, hydrocarbons form a separate phase on top of the SELEXOL solvent phase and can be decanted from the solvent. There are several patented techniques to prevent this phenomena from occurring in a SELEXOL solvent unit and in some cases for exploiting it.

The solubility of hydrocarbons has been found to decrease with increasing water concentration in the SELEXOL solvent solution. In Table 2, it is shown that by increasing the water content of SELEXOL solvent from 1 % to 3% the solubility of each hydrocarbon component decreases, but to varying degrees. The effect of water on hydrocarbon solubility becomes more pronounced as molecular weight increases.

Table 2. The Effect of Water on Hydrocarbon Solubility in SELEXOL Solvent at 75°F-80°F

Component	Percent Decrease in Solubility
C ₁	8
C ₂	23
C ₃	32

A process has been patented for using water to remove hydrocarbons from SELEXOL solvent and other physical solvents.

Dehydration

The solubility of water in SELEXOL solvent is 1683 times as great as that of ethane (See Table 1). In fact, water is absorbed more readily than any component shown in the table except HCN. SELEXOL solvent does not require mixing with water and in most cases water is taken away from the system as opposed to being required as makeup. Depending on the treated gas, water specification, it may not be necessary to install supplemental dehydration equipment especially if the unit incorporates a lean solvent chiller.

European Distribution Company Selexol Solvent Peak-Shaving Plants

A European distribution company chose SELEXOL solvent for five gas Pre-treatment Units. The European distribution company's pipeline grid covers several countries and it is the primary domestic gas supplier in the region. Since it is essential that the gas supply is dependable and uninterrupted, the European distribution company liquefies a portion of the gas supply during time of low demand. The stored LNG is then vaporized to supplement the gas supply during times of peak demand.

In the past, a portion of the pipeline gas was simply treated by molecular sieves to reduce the carbon dioxide, ethane, and heavier components prior to liquefaction. However, over time, the carbon dioxide and hydrocarbon levels in the natural gas supply have steadily increased, forcing a decision to invest more in molecular sieves or seek an alternative technology. SELEXOL solvent was chosen because of its ability to easily absorb carbon dioxide, ethane, and heavier hydrocarbons over the expected range of concentration increase.

In the European distribution company's process a portion of the pipeline gas is directed from the pipeline to a SELEXOL solvent Pretreatment Unit where carbon dioxide and C2+ components are removed so that the original upstream molecular sieve units can still be operated efficiently. After treatment in the molecular sieve units, the gas is liquefied and stored until demand increases during the winter months.

The first plant was started up in October of 1992. The second plant was started up in June of last year. The two plants that are built and the three plants slated to be built all have the same basic design, differing mainly in size because of differing feed quantities.

European Plant: Process Description

A simplified Process Flow Diagram of the European plant is shown in Figure 3. Feed gas enters the absorber and flows counter currently with SELEXOL solvent. Treated gas exiting from the top of the absorber goes through a knockout pot and a filter separator to remove any condensable hydrocarbons and entrained SELEXOL solvent. The gases flashed from each of the flash tanks, the reject gas, is recompressed and redirected to the reject gas pipeline and eventually back into the supply pipeline.

Lean solvent is chilled to 25°F which absorbs carbon dioxide and coabsorbs some of the hydrocarbons. The rich solvent from the absorber bottom is regenerated by letting the pressure down through a series of flashes. The rich solvent is first flashed in the high pressure flash tank from 603 psia to 106 psia and then the medium pressure to 16 psia and the vacuum flash tank to 3 psia. The SELEXOL solvent from the last flash, now lean, is pumped through the lean solvent chiller, which uses propane refrigeration, and is recycled back to the top of the absorber.

European Plant: Operations

The European Plant was designed to meet a treated gas specification of a maximum of 0.50 mole % carbon dioxide and a maximum of 6.5 mole % ethane and heavier components. The feed gas enters the SELEXOL solvent unit at 32°F and 603 psia. The plant is designed to handle a feed volume of 26 mmscfd with up to a 70% turndown to accommodate variation in the feed. Table 3 compares the feed and treated gas streams showing that the specifications are achieved. The treated gas contains 0.29 mole percent CO₂ and 5.33 mole percent ethane.

**European Plant:
Operations cont.**

Note that the partial pressure of carbon dioxide is only 14.5 psia in the inlet gas, whereas the partial pressure of carbon dioxide in the inlet gas of typical SELEXOL solvent applications is 30 psia minimum.

An additional benefit of the SELEXOL Solvent Process is the inherent water removal capability. Water is reduced from 75 ppmv in the feed gas to 12 ppmv in the treated gas which unloads the downstream molecular sieve units. Hydrogen sulfide and methyl mercaptan were also reduced from 2 ppmv

Figure 3. European Distribution Company Facility, SELEXOL® Solvent Process

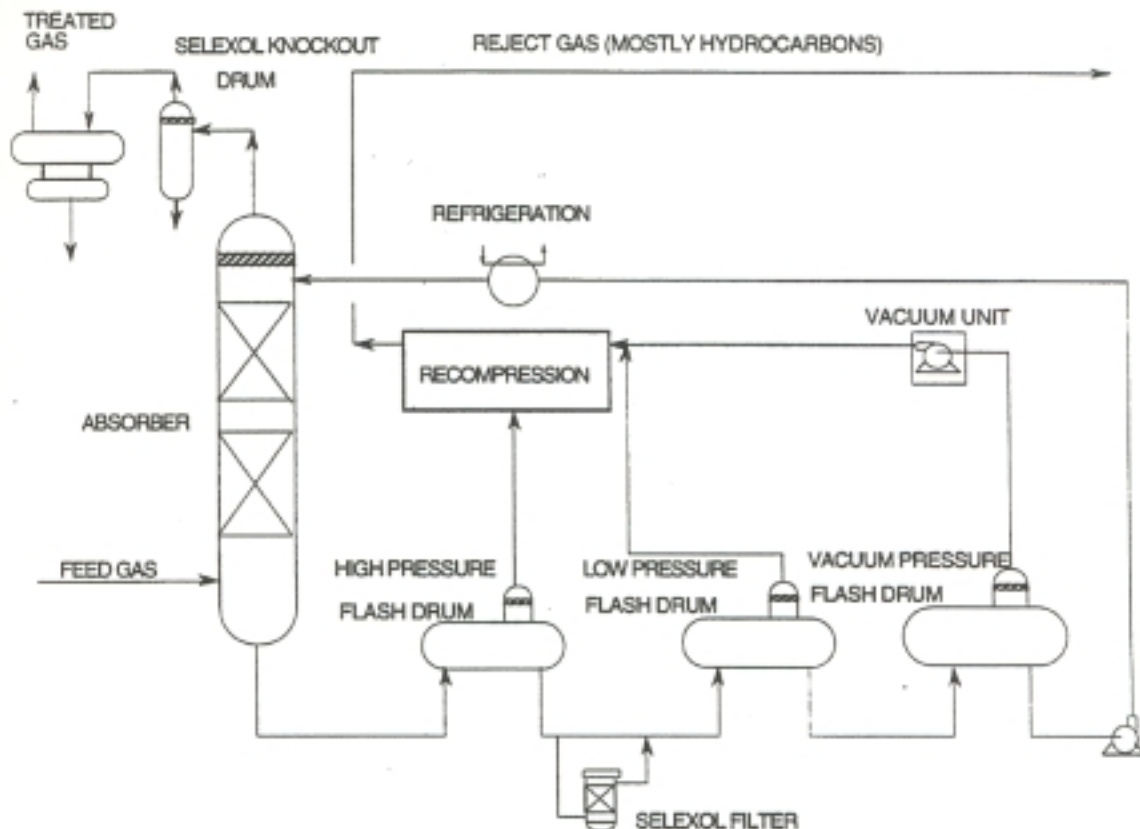


Table 3. European Distribution Plant SELEXOL® Solvent Unit Inlet and Outlet Composition

Component	Inlet Gas Composition Mole %	Outlet Gas Composition Mole %
H ₂ S	0.0002	—
CH ₃ SH	0.00050	0.00012
CO ₂	2.44	0.29
N ₂	0.785	0.88
Methane	86.317	93.02
Ethane	7.539	5.33
Propane	2.403	0.35
i-Butane	0.119	0.02
Butane	0.303	0.07
i-Pentane	0.0080	0.002
Pentane	0.059	0.016
Hexane	0.008	0.003
Heptane	0.005	0.003
n-Decane	0.002	0.000
Water	0.008	0.001

and 5 ppmv in the feed gas to 0.3 ppmv and 1.2 ppmv respectively, in the treated gas.

One problem that the European facility encountered was foaming in the flash vessels. Though SELEXOL solvent is more forgiving than most solvents, it will foam under certain conditions. Laboratory tests showed that the heavier hydrocarbons induced foaming in SELEXOL solvent.

The heavier hydrocarbons have lower volatility and hence residual amounts are likely to be left in solution after flashing. It was found that foaming could be reduced significantly by raising the temperature in the flash vessels slightly. By increasing the temperature in the flash vessels more hydrocarbon vapors are evolved and the solution viscosity is reduced, which helps to reduce the foaming. Also, a silicone-based antifoam was used and found to be very effective.

Tejas Power Plant

A SELEXOL solvent plant was started up in December, 1992 at the Tejas Power Corporation's Galveston Island Gathering System (GIGS) facility. The facility receives gas from its offshore gathering system and delivers to the Dow and Amoco pipelines. The gas has to meet the standard pipeline water content specification of 7 lbs/mmscf. In addition, a hydrocarbon dewpoint of 32°F is required to prevent hydrocarbon liquids from condensing in the line.

The SELEXOL solvent plant replaced two glycol units. They had adequately dehydrated the gas but did nothing about the hydrocarbon liquids in the gas which were beginning to cause problems with one of the downstream gas purchasers. Other options were considered, such as a refrigeration plant, but were deemed too costly.

Tejas Power Plant: Process Description

The Tejas Power Plant is similar to an amine plant in terms of layout. (See Figure 4.) The feed gas flows through a filter separator at the inlet to remove any entrained liquid hydrocarbons, excess water and dirt. The gas then flows into the bottom of the absorber and countercurrently contacts the SELEXOL solvent. Treated gas exiting from the top of the absorber goes through a filter separator to remove any entrained SELEXOL solvent.

As SELEXOL solvent is flowing down the column, hydrocarbons are absorbed from the feed gas. The rich solvent from the absorber bottom is first flashed, releasing a portion of the hydrocarbons in the vapor. The rich liquor from the flash tank is then heated by countercurrent heat exchange with lean solvent from the regenerator, and is fed to the top of the regenerator. The rich solvent flowing down the regenerator column is stripped by steam generated in the reboiler. The overhead vapors, consisting of hydrocarbons and steam, are condensed and accumulated in a threephase separator. Condensed hydrocarbons are recovered; a portion of the water is recovered and a portion is recycled back to the top of the regenerator as reflux. Lean solvent from the reboiler is pumped through the rich/lean exchanger, through an air-fin cooler and back to the top of the absorber.

Tejas Power GIGS: Operations

The Tejas GIGS SELEXOL solvent plant has been operated effectively over a wide range of conditions since startup. The SELEXOL solvent circulation rate has been varied between 25 and 43 gpm with a feed gas rate ranging from 89 to 114 mmcsfd. The raw gas feed made up of a mixture of aliphatic and aromatic hydrocarbons comes into the absorber at 76°F and 865 psia and has a hydrocarbon dewpoint of 70°F and a water level in excess of 32 lbs/mmcsf. The requirements for the treated gas are a 38°F hydrocarbon dewpoint depression and 7 lb/mmcsf water level.

**Tejas Power GIGS:
Operations cont.**

Table 4 shows that more than half of the heavier hydrocarbons are absorbed, mostly those above C7. These absorbed hydrocarbons are recovered as condensate. An average of 60 to 65 barrels of condensate and 4 to 5 barrels of water are produced from the SELEXOL solvent unit per day.

It has been discovered that the SELEXOL solvent circulation rate has less bearing on the hydrocarbon pickup, hence dewpoint, than does the ambient temperature. A quick indication of hydrocarbon dewpoint is obtained from C6+ readings from the field chromatograph. In the summer months, the C6+ readings average about 0.10 -0.11 mole %, whereas in the winter months, the reading has gone as low as 0.088 - (1) .095 mole %. Figures 5 and 6 show the phase envelopes for the inlet and outlet streams. Figure 6 shows the cricondentherm at -24°F and that the dewpoint is well below freezing throughout the range of 30 psia to 1000 psia. Although the gas outlet pressure is 860 psia, the pressure will be reduced at various points along the pipeline and any of these pressure drops could cause formation of liquids in the line if the dewpoint is not sufficiently reduced. (2) Normally the water content runs about 4-5 lb/mmscf, but when the ambient temperature is high it becomes difficult to consistently keep the level below 7 lb/mmscf. Therefore, the original dehydration equipment has been reactivated but is operated at one-tenth the load that it was previously. To alleviate the problems associated with fluctuations in temperature, the lean solvent could have been refrigerated. However, the economics would not justify a refrigeration unit.

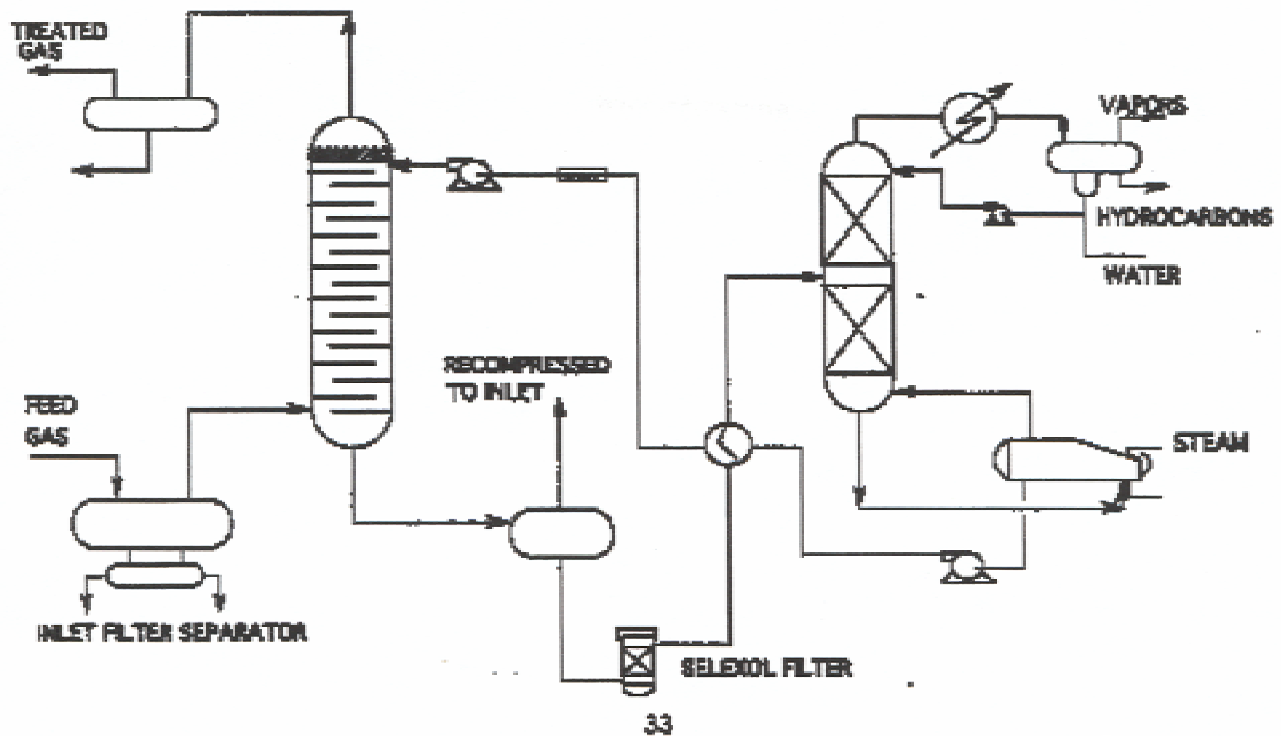


Table 4. Tejas Power Corporation GIGS SELEXOL® Solvent Plant – Inlet and Outlet Composition

Component	Inlet Gas Composition	Outlet Gas Composition
	Mole %	Mole %
N ₂	0.2545	0.2797
CO ₂	0.5619	0.6993
C ₁	96.7147	97.145
C ₂	1.8528	1.871
C ₃	0.5238	0.456
IC ₄	0.2555	0.212
NC ₄	0.1790	0.144
IC ₅	0.1012	0.074
NC ₅	0.0650	0.044
2,2 DMC ₄	0.0085	0.005
2,3 DMC ₄ & CYC ₅	0.0112	0.005
2MC ₅	0.0350	0.015
3MC ₅	0.0148	0.006
NC ₆	0.0307	0.010
2,2 DMC ₅	0.0141	0.005
MCYC ₅	0.0023	-
2,4 DMC ₅	0.0007	-
Benzene	0.0288	-
3,3 DMC ₅	0.0116	0.004
2MC ₆	0.0128	0.001
2,3 DMC ₅	0.0007	-
1,1 DMCYC ₅	0.0082	0.001
1, T-3 DMCYC ₅	0.0019	-
1, C-3 DMCYC ₅ & ₃ EC	0.0023	-
1, T-2 DMCYC ₅	0.0037	0.001
NC ₇	0.0163	-
223TMC ₅ & ₂ 5DMC ₆	0.0150	0.001
1, T-2 C-4TMCYC ₅	0.0031	-
1, T-2 C-3TMCYC ₅	0.0011	-
2,3,4 TMC ₅	0.0010	-
Toluene	0.0198	-
2M3ECYC ₅	0.0074	-
3,4DMC ₆	0.0038	-
3MC ₇	0.0033	-
1, C-3DMCYC ₆	0.0010	-
1, 1DMCYC ₆	0.0007	-
NC ₈	0.0104	-
1, T-2DMCYC ₆	0.0005	-
2,5DMC ₇	0.0006	-
NC3CYC ₅	0.0007	-
ECYC ₆	0.0020	-
3,3 DMC ₇	0.0028	-
E-Benzene	0.0032	-
M&P Xylene	0.0092	-
NC ₈	0.0027	-
3MC ₈	0.0004	-
IC4CYC ₅	0.0016	-
O-Xylene	0.0015	-
NC ₉	0.0063	-
IC ₃ Benzene	0.0012	-
2,2 DMC ₈	0.0030	-
IC3 CYC ₆	0.0023	-
2,3DMC ₈	0.0008	-
IC3 CYC ₆	0.0023	-
2,2 DMC ₈	0.0030	-
NC4 CYC ₅	0.0010	-
3,3 DMC ₈	0.0004	-
Unidentified	0.0012	-
M E-Toluene	0.0013	-
P E-Toluene	0.0014	-
2MC ₉	0.0015	-
3MC ₉	0.0011	-
SEC C ₄ Benzene	0.0003	-
NC ₁₀	0.0037	-
C ₁₁₊	0.0034	-

Figure 5. Tejas Power – Phase Envelope for Inlet Stream

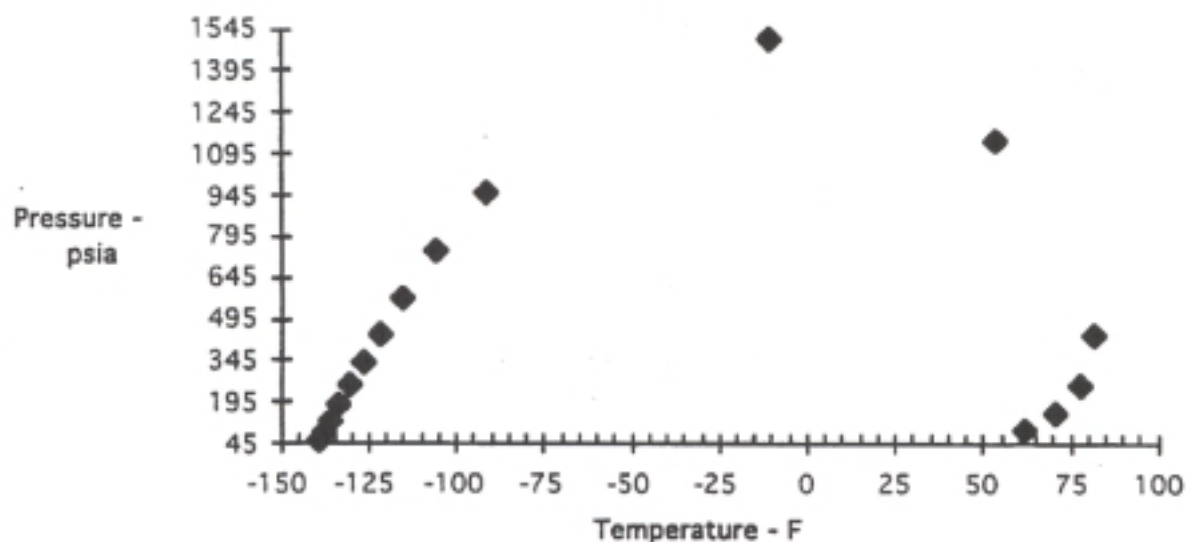
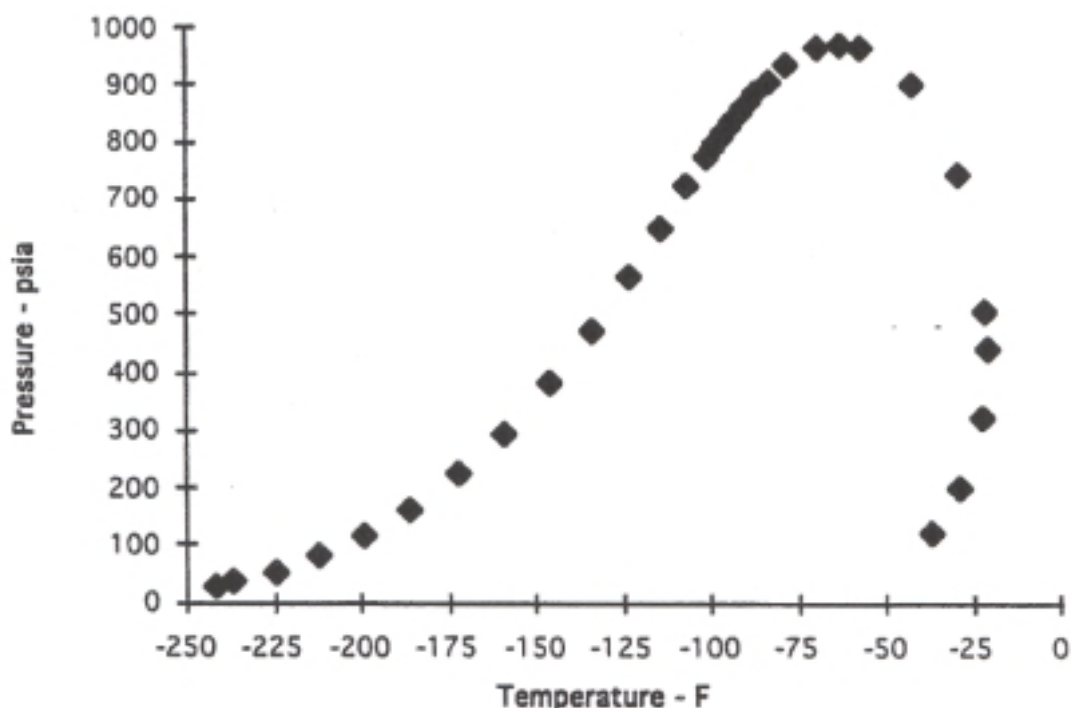


Figure 6. Tejas Power – Phase Envelope for Outlet Stream



Conclusion

It has been recognized for some years that SELEXOL solvent can be used for both gas treatment and hydrocarbon recovery. (3) This paper has presented details of two plants operating within a new market niche. It has been shown that using the SELEXOL solvent for hydrocarbon removal upstream of cryogenic plants and for hydrocarbon dewpoint control in pipelines is a costeffective alternative to conventional methods. In the future, SELEXOL solvent facilities will be built to remove acid gases, control hydrocarbon dewpoint, and dehydrate gas streams in one unit. Several of these units have already been specified and designed.

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